ROADS FOR WATER SECURITY
WATER FOR ROADS SAFETY

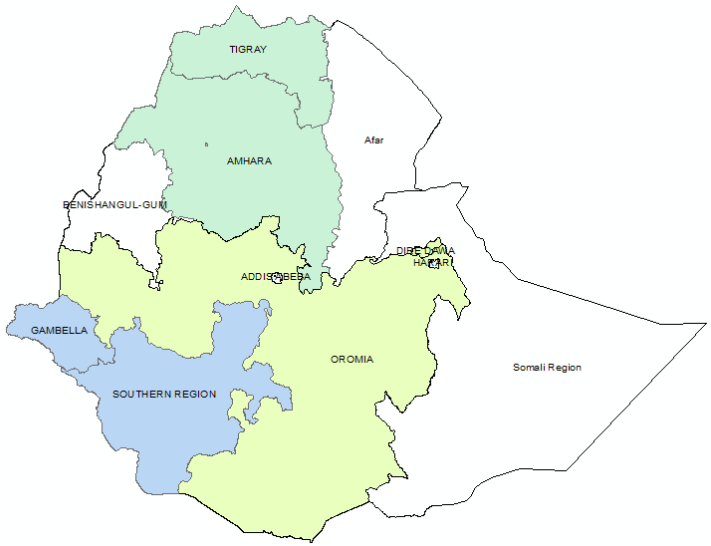
Road Water Management: Design Considerations

Why design considerations for RWM?

Observations:

Assessment for the need for design consideration for RWM is done in all intervention areas:

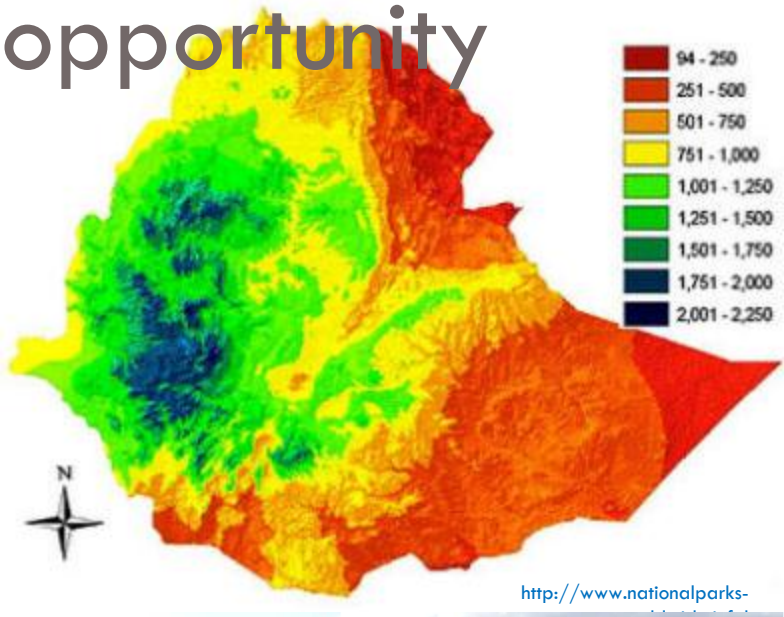
- Ethiopia
  - Tigray & Amhara RSs
  - Dire Dawa Admin.,
  - Oromia, SNNPR, Gambela RSs
- Kenya
- Uganda
- Bangladesh



Why design considerations for RWM?

To make use of the huge opportunity

- As compared to many countries that have lower rainfall amount, the rainfall in Ethiopia ranges between less than 200 mm in some parts of the northern and south-eastern lowlands to 2700 mms in south-western highlands.
- The physiographic set up- undulating, hilly and mountainous geomorphology (Contributes to high flow reaching the arable land).
- Better highland-lowland hydrologic link



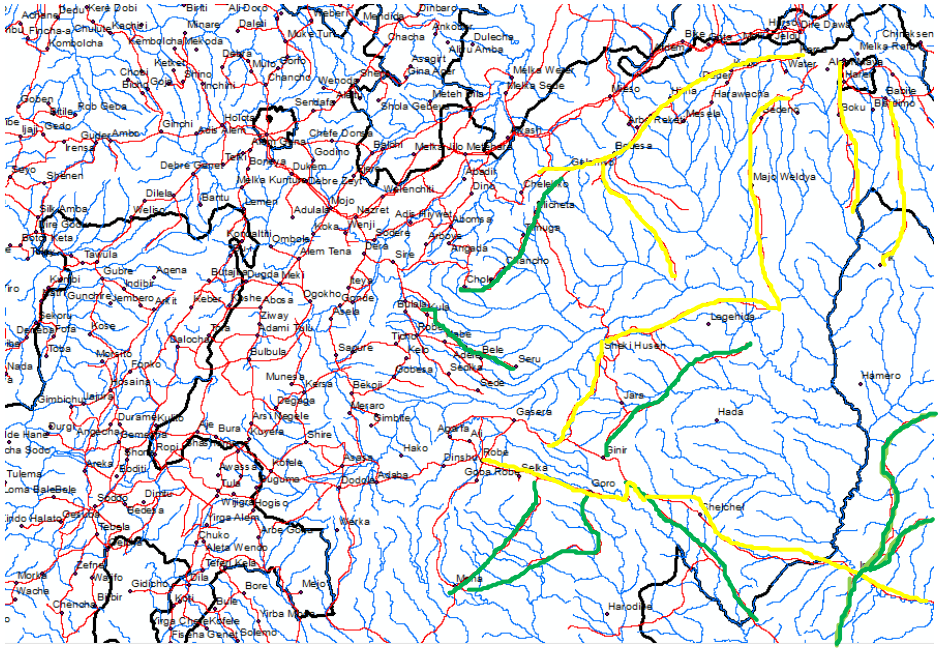
http://www.nationalparks-

Opportunity....

- The road sector in Ethiopia is one the fast growing
- Exponentially growing road water harvesting potential/opportunity
- During the past three decades road density/1000 sq.km (including community roads) has risen from 24 km to more than140km
- The19,017 kms road ~24 years ago, with an annual average increment of 18.8%, has now reached 105,000 km (ERA, 2009, Ibid 2015).
- The increase is also happening in water stressed areas
- Planed to build more than 100,000 kilometers of roads in GTPII

Missed opportunity

- Most roads are built on water divides, parallel to major rivers but across small rivers and streams
  - Modify watersheds but added benefit if R4W is implemented



Missed opportunity…

- Create substantial opportunities for productive use of water
  - Improved soil fertility
  - Supplementary irrigation
  - Roadside plantation
  - Water for livestock, human (when treated)
  - Improved ecosystem
- More accessible and inhabited to make R4W easy for implementation
  - High demonstration effect

Modify watersheds

- Harm to downstream users
  - Flood and erosion hazard
  - Reduced recharge and moisture availability
- Blockage on upstream side

To minimize the damages to roads

- If not well handled water is No. 1 enemy of roads the most appropriate way to do this is making the enemy a friend
- In Ethiopia water typically is the cause of 35% of the damage on paved roads and close to 80% on unpaved roads. Problematic drainage is the most common factor in construction delays

To minimize …

- Reduced maintenance burden among others by uphill watershed protection,
- Reduced damage from uncontrolled run-off on unpaved roads (a major issue) and reduced risk of gully damage

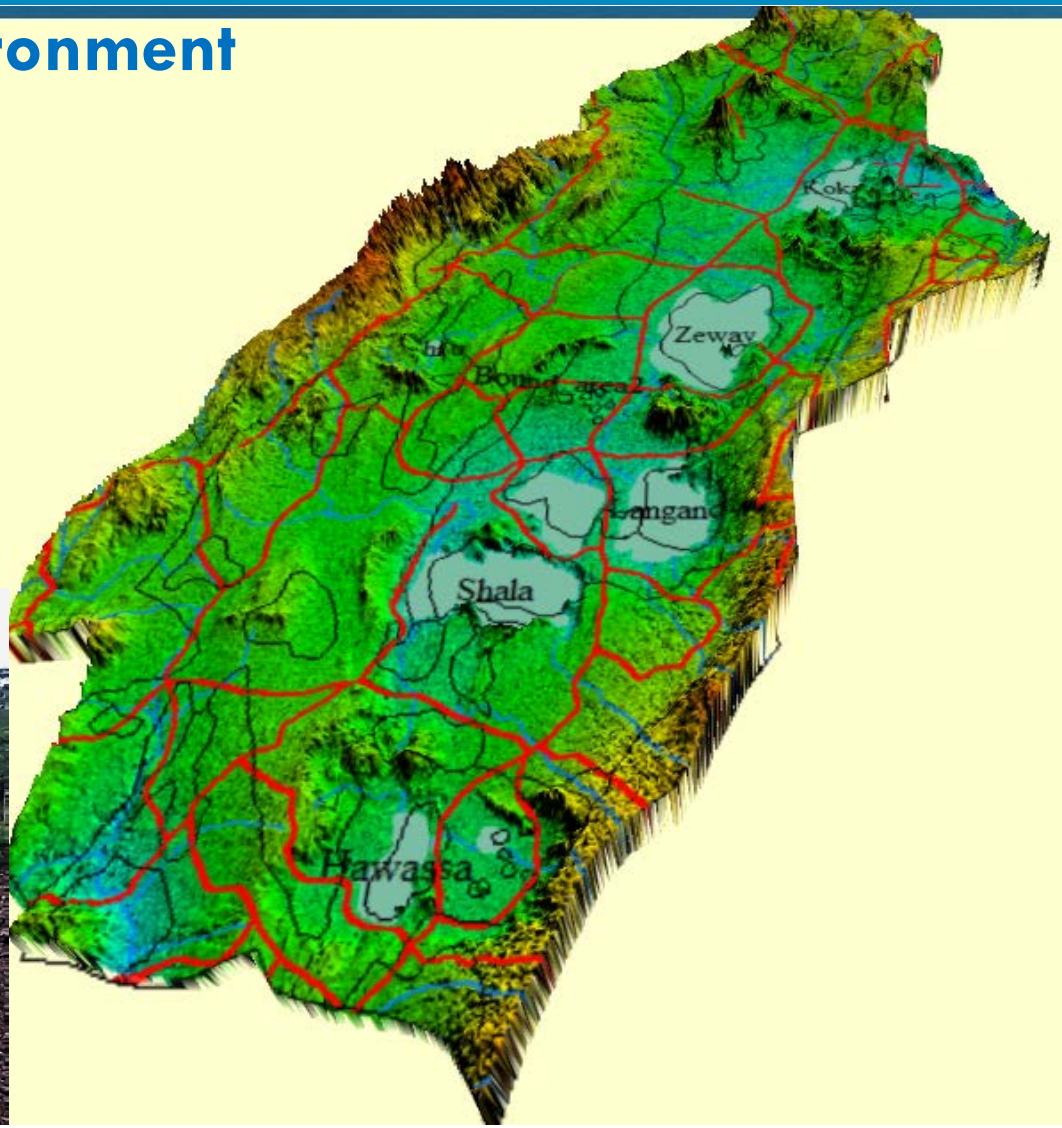
To minimize …

- Reduced risk of road induced flooding and water logging
- Reduce erosion and sedimentation

For better consideration of the hydro-ecosystems

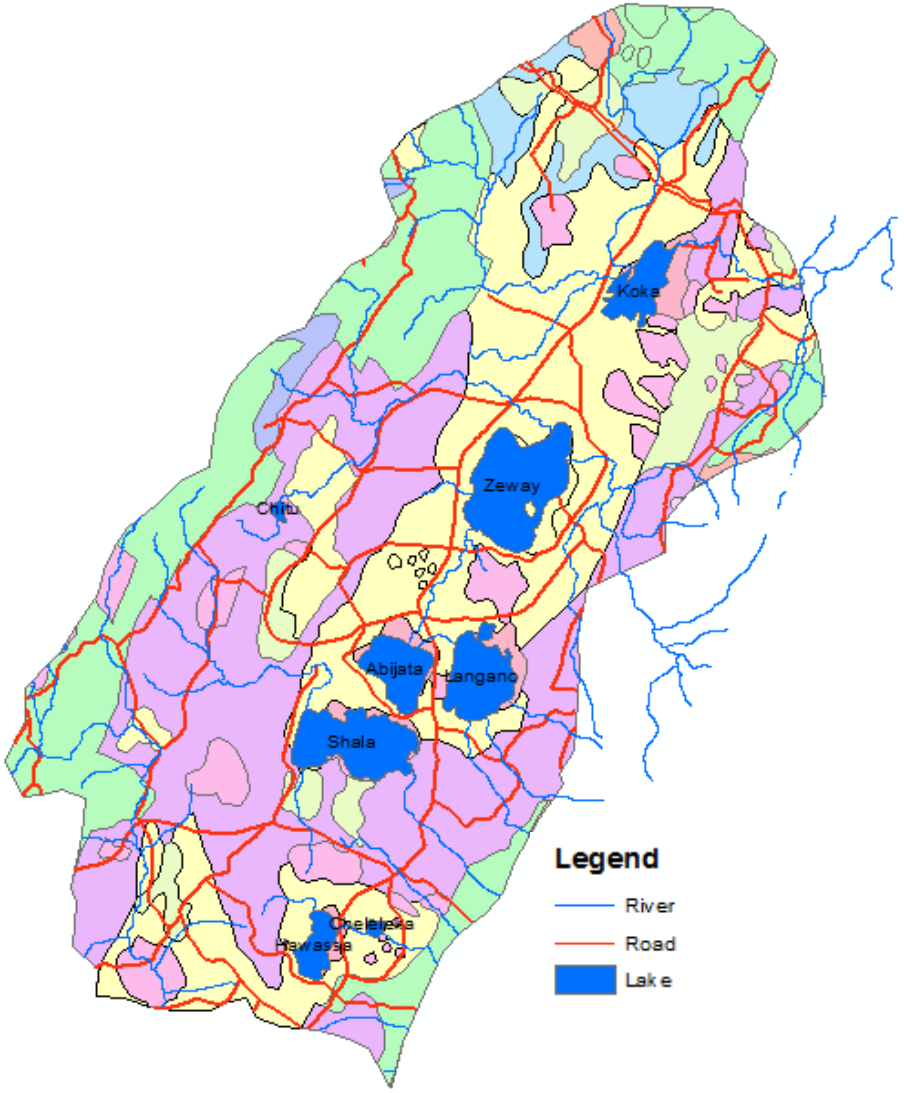
the rift valley lakes environment

- Reduced flow to the reservoirs
- Damage to the roads, particularly in such high rainfall years



the rift valley lakes environment…

- Vulnerable geological formation and rift structures are the main controlling factors



the rift valley lakes environment….

- Floods on the upstream side of roads

To tackle roads impacts on wetlands & excess rainfall situation

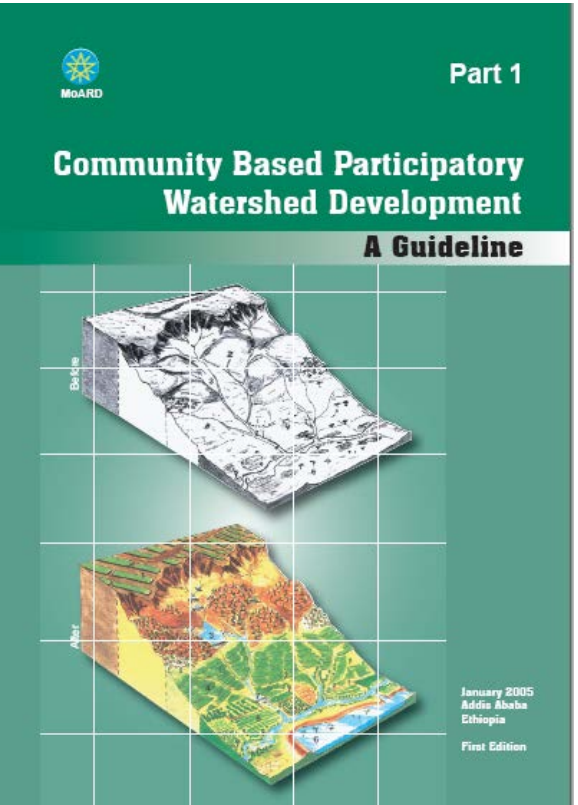
Impacts also depend on hydrological responses – impoundments may or may not create wetlands

Existing approaches and guidelines

- Each sector (road, water, agriculture) has its own guidelines and manuals to do its mandated task.
- The road sector guidelines never consider the beneficial use of water.
- The agricultural sector consider roads as aggravating land degradation
- The modification to the hydrology by roads is a concern for the water sector

The need for a common guideline

- To bridge the gap between the key actors by:
  - Linking the various sectoral guidelines and manuals by adding the missing links to address RWM



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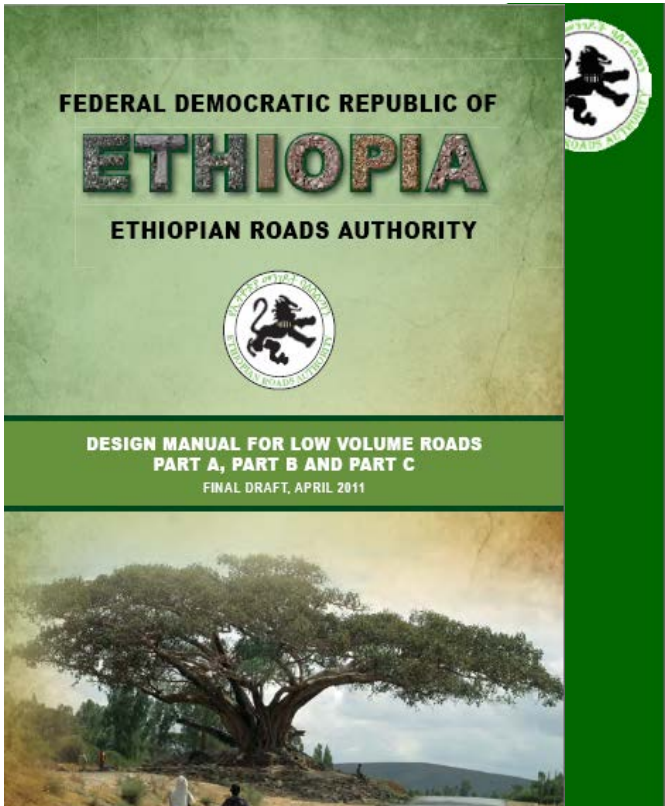


The Guideline Preparation

Process & Status

- MoU signed with ERA
  - follow-up and support
  - endorse the GL and recruited lead freelance consultants
- Based on initial tentatively agreed contents

ToR for the whole process is prepared

Guideline Preparation Task Team (GPTT)

- The preparation of the Guidelines is a team work
- A multidisciplinary task team consisting highly qualified, experienced and professionals is established.
- The **GPTT** is composed of individual consultants drawn from Metameta, Mekele University, ERA Staffs and freelance consultants proposed by ERA.
- Professionally, the team is composed of well experienced-high level professionals including highway engineer, structural engineer, hydrologist, geotechnical engineer, environmentalist and socioeconomist.

International Reference Group/Team (IRG)

- An international reference group consisting **highly qualified professionals** with international experiences and having two to three members will be formed.

- The international team will be responsible to review the Guidelines at its intermediate and final stages.

- It will also create connection with other countries in the AFCAP network; for instance through a regional committee.

What is in the guideline?

Annex - Agreed Table of Contents

ERA Guidelines for Road Water Management

1. Introduction
    - Importance of multi-functional road development to create resilience
    - Characterization of road water harvesting in different types of road catchments and type of settings (lowland, highland/ agriculture, forest, pastoralist areas)
    - General guidelines for road development
    - General guidelines for road maintenance
2. Current practices of road water management in Ethiopia
3. Calculating catchment run-off and direct-road run-off
4. Principles of Road Water Management
    4.1 What is Road Water Management for Climate Resilience
    4.2 Water Harvesting Principles
5. Planning of a road project considering water harvesting
    - Site Investigation Stages
    - Route selection for high volume roads
    - Road Location of low volume roads
    - Reusing borrow pits and quarries for water harvesting
6. Road Water Management Techniques
    - Water storage systems
    - Erosion Protections and water guiding systems
    - Surface Drains
    - Subsurface Drains
    - Diversion structures

What is in the guideline?....

7. Drainage design and road surfaces
    - Water harvesting from drains
    - Sand harvesting from drains
8. Design of culverts and associated structures
    - Culvert placement (concentrated or distributed road drainage)
    - Culvert design
    - Culvert size
    - Fish passage from culverts
    - Downstream erosion control
    - Water spreading from culverts
9. Road side water harvesting structures
    - Storage ponds (location and dimensions)
    - Infiltration ponds (location and dimensions)
    - Deep trenches (location and dimensions)
    - Soak pits
    - Lining
10. River crossings
    - Using fords and low causeways as sand dams
    - Using fords and low causeways as river bed stabilizer or flood water spreaders

What is in the guideline?....

11. Developing road side vegetation

12. Landscape management around roads
    - Erosion and run-off control
    - Avoiding and preventing landslides
    - Avoiding sand dune formation

13. Roads and wetlands and flood management
    - Roads in low lying flood plains
    - Contribution of roads to flood control
    - Roads as embankments and evacuation areas
    - RWM in wetlands

14. Geotechnical considerations for water harvesting from roads
    - Water storage ponds
    - Roadside drainages
    - Culverts and bridges
    - River crossings (fords, etc.)
    - Road embankments for water storage

15. Sub-surface drainages from road slopes
    - Types and locations
    - Road side spring capture and protection and seepage management
        - Spring safety
        - Safe access
        - Dimension upstream or downstream
        - Roads and seepage management

What is in the guideline?

16. Generalized Spatial Guide for RWM and Water Harvesting

17 Defining access to road water harvesting benefits
- Access to land and water
- Gender considerations

18 Water quality issues related to RWM
a. From bitumen surface
b. From urban, industrial and domestic waste

19 Health and Environmental issues related to RWM
a. Malaria
b. Water related diseases
c. Environment

20 Community and stakeholder engagement in road water harvesting
a. Community resource planning
b. Coordination with watershed programs

21 Legislations & Guidelines Relevant to RWM

(Incorporate indigenous knowledge)

Some highlights

Design consideration at Site Investigation Stages

- As per ERA's Site Investigation Manual 2013 chapter 1 section 1.4, site investigation is required at all stages in the development of a road project.
- Consider RWM in all four stages leading up to and including Final Engineering Design. These are;
  - Identification and general planning
  - Pre-feasibility study
  - Feasibility or Preliminary Engineering Design
  - Final Engineering Design

Some highlights….

6.1. Water storage systems

Water storage systems			
Options	Possible area of application	Design Consideration	Remarks
Detention/retention basin	▪ Upper slope catchment area ▪ Down slope area	▪ Topography ▪ Soil types and their infiltration ▪ Land use and land cover ▪ Catchment area and rainfall intensity ▪ Community needs ▪ Availability of land for basin development ▪ Distance of the basin from road and its effect on the safety of the road	❖ the location of the basin should be outside of the road reserve
Micro basin-from soil berm	▪ Upper slope catchment area ▪ Down slope area	▪ Topography ▪ Soil types and their infiltration ▪ Land use and land cover ▪ Catchment area and rainfall intensity ▪ Seasonal characteristics of stream flow ▪ Community needs ▪ Availability of land for basin development ▪ Distance of the basin from road and its effect on the safety of the road	❖ micro basin are generally suitable to construct at locations with low storm water flow ❖ the location of the basin should be outside of the road reserve ❖

Some highlights….

6.2. Erosion Protections and water guiding systems

Erosion protections and water guiding systems			
Options	Possible area of application	Design Consideration	Remarks
Packed or dumped rock riprap	▪ Upper slope catchment area ▪ Down slope area ▪ Rolling to mountainous terrain ▪	▪ Topography ▪ Soil types and their erodiblity ▪ Availability of construction material source	❖ It enhances recharging by slowing down the run-off ❖ Serves as streambed erosion protection by reducing the scour in erodible canal
Check dams dry and mortared	▪ On side ditches ▪	▪ Road/ditch gradient ▪ Soil types and their erodiblity ▪ Catchment area and rainfall intensity ▪ Community needs ▪ Availability of construction material source	❖ It provides proper guide of ditch flow, especially in steep gradient road sections, to water harvesting systems ❖ It helps to minimize sedimentation to water harvesting systems and protects erosion

Some highlights….

6.3. Surface Drains

Surface Drains			
Options	Possible area of application	Design Consideration	Remarks
Furrow/intercepting ditches	▪ Top of mountain ▪ Top of deep cut section ▪ Intercepting ditches at the top and bottom of the slopes	▪ Topography ▪ Soil types and their erodiblity ▪ Slope stability ▪ Cut depth	❖ Enhance slope stability ❖ To control the flow of water: flow can be directed to nearest water harvesting system
Miter drains/ ditch out	▪ On side ditches/drains: to provide flow relief of the side drain	▪ Length of side drains ▪ Road/ditch gradient ▪ Soil types and their erodiblity ▪ Catchment area and rainfall intensity ▪ Community needs	❖ Commonly practiced in many water scarcity areas of the country to guide water from side drains to farm land and other water harvesting systems

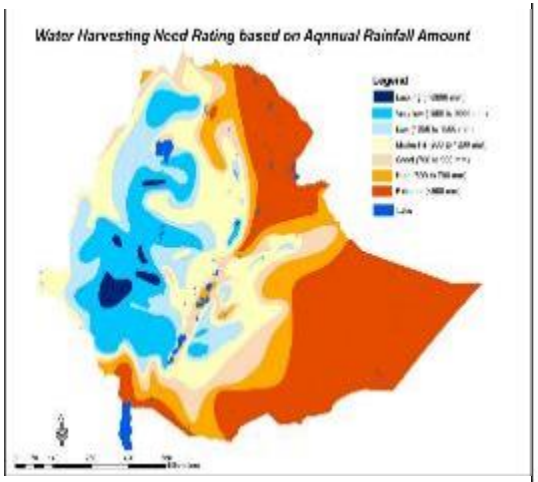
Some highlights….

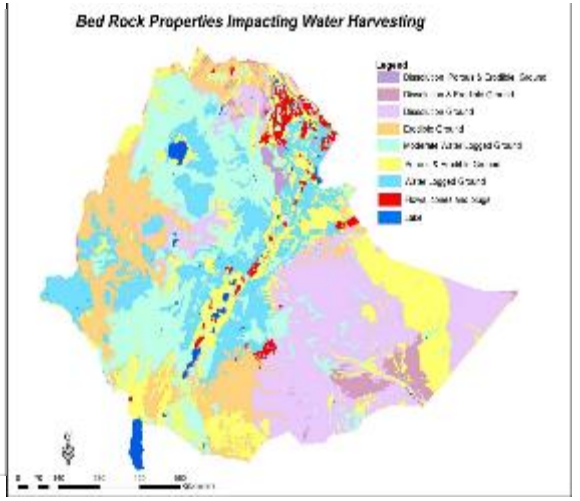
6.4. Subsurface Drains

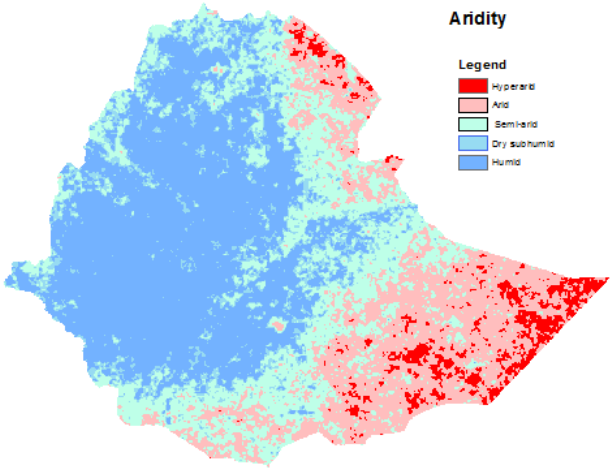
Subsurface Drainage Systems			
Options	Possible area of application	Design Consideration	Remarks
French drain	▪ Through side drains: especially in water logging area and springs ▪	▪ Topography ▪ Road/ditch gradient ▪ Amount of subsurface water ▪	❖ It is rock field trench ❖ Collects subsurface water and protects the road subgrade from saturation
Slotted or perforated uPVC pipes	▪ Through side drains: especially in water logging area and springs	▪ Topography ▪ Road/ditch gradient ▪ Amount of subsurface water ▪ Diameter of slotted or perforated pipe ▪ Use of geotextile filter fabric	❖ Rock fill to a certain depth from invert and filled with impermeable back filling ❖ Collects subsurface water and protects the road subgrade from saturation

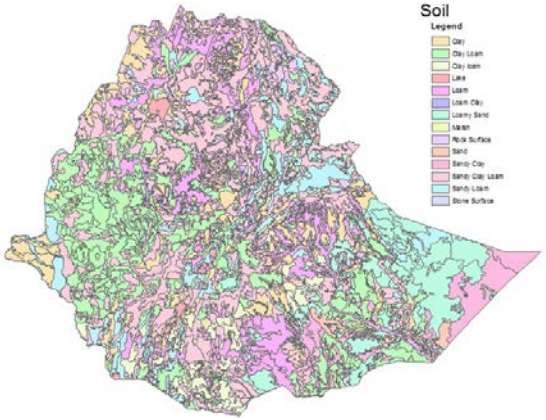
Some highlights….

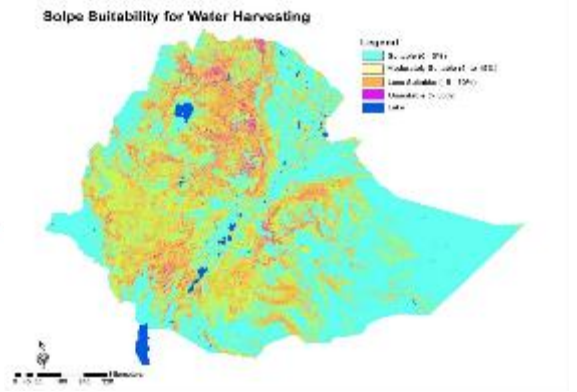
Provide interactive spatial guide based on homogenous planning units for BRWM/WH containing the most determinant factors











Some highlights….

Generalized Interactive Spatial RWM/WH Planning Guide

Parent Geology			Major derived soil texture type	Recommended WH Technology and Most Suitable Areas						Aridity Index	Map Code
Rock Group	Rock Type	Potential Threat for WH		Technology type (in priority order)	Agro-ecological zone*			RF Range	Slope range		
					Sub-humid	Semi-arid	Arid				
Crystalline Basement/Metamorphic Rocks											
Acid metamorphic rocks	– Schist, quartzite, gneiss, migmatite, slate, phyllite, pelitic rocks	– Leaking Structures-faults, joints fractures	unconsolidated soil layer & regoliths	Sand dams, Check dams, lined ponds, recharge wells, others	✓	✓	✓	<1200mm	0 to 50%		
			Hard rock surface	Rock surface water harvesting	✓	✓	✓	All range	0 to 50%		
Basic metamorphic rocks	– Schist, slate, phyllite, pelitic rocks, green, schist, gneiss rich in Fe–Mg minerals, marble, amphibolite…	– Leaking Structures-faults, joints fractures	unconsolidated soil layer & regoliths	Sand dams, lined ponds, recharge wells, check dams, others	✓	✓	✓	<1200mm	0 to 50%		
			Hard rock surface	Rock surface water harvesting	✓	✓	✓	All range	0 to 50%		
Ultrabasic metamorphic rocks	– Serpentinite, greenstone,	– Leaking Structures-faults, joints fractures (check for heavy metal concentration, objectionable test & odour) - Water logging,	Coarse-grained sand/Sandy soils/sandy loam	Sand dams, lined ponds, check dams & others		✓	✓	<1200mm	0 to 50%		
			Hard rock surface	Rock surface water harvesting		✓	✓	All range	0 to 50%		

UNPAVED ROADS

Planning low volume roads

- Road location
- Alternating of slopes
- Reducing erosion

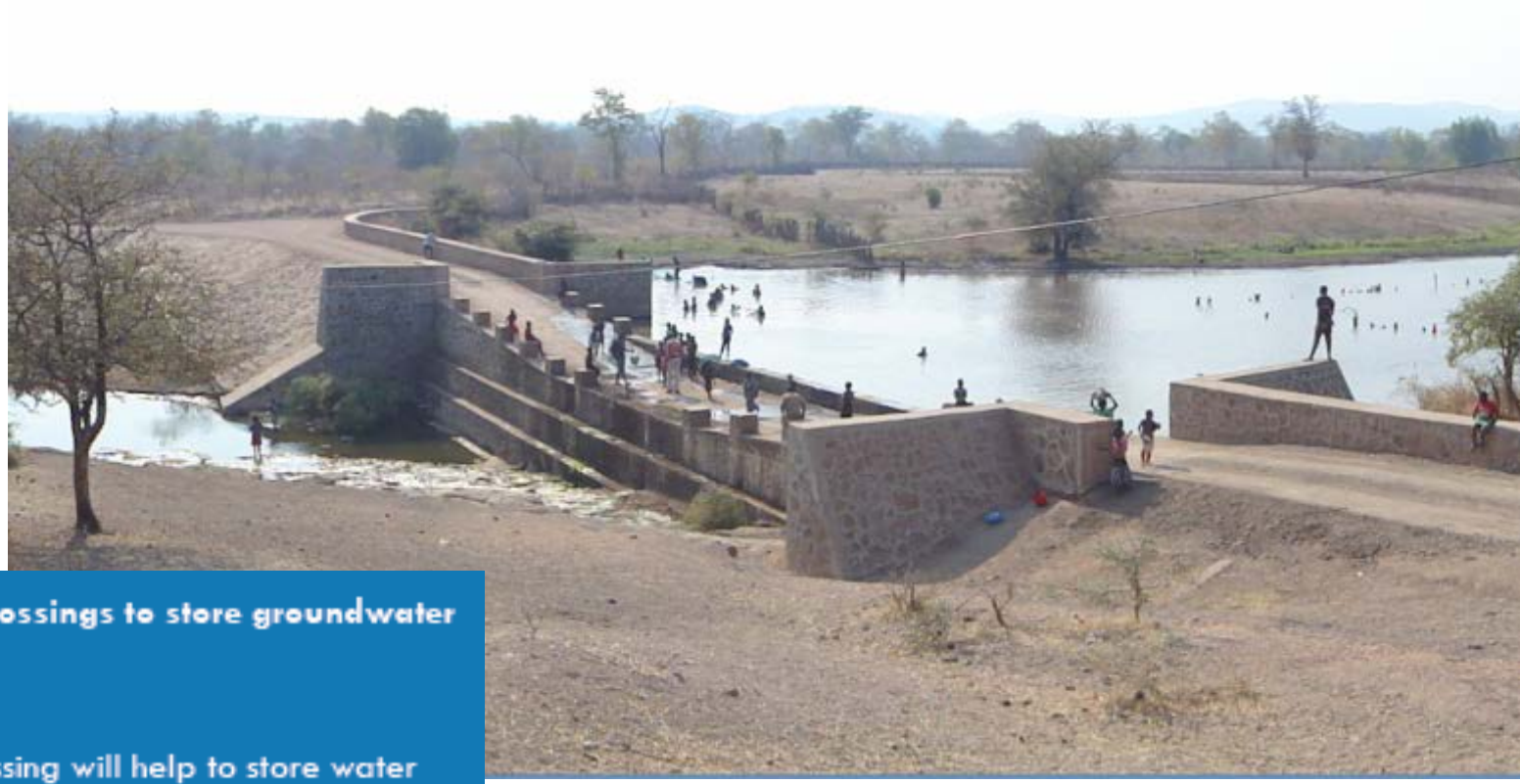
Water bars on unpaved roads to avoid flooding of road

- Make small water bars at unpaved roads at regular distance – this avoids road erosion and helps to harvest water from the roads
- If the road is steep make these water bars at shorter distance
- Make water bars at angle with roads to guide the water away from the road
- Divert the water to land or grazing area

- Avoid flooding of adjacent land

Have adequate water bars, rolling dips and lead-out drains at the right locations

ROAD CROSSING



Using road crossings to store groundwater upstream

- Road crossing will help to store water upstream in the river bed which will re-charge wells
- If the river is sandy this can store a good quantity of water
- If the river is broad a sand dam without culverts will stabilize the river bed
- If the road crossing is connected to the bed rock it will act as full sand dam

- Make sure there is a spillway for high floods

Go for non vented (no culvert) fords
Anchoring on bed rock affects water rights

Converted borrow pits and quarries

Converting borrow pits to store water from roadside drains and culverts

- Connect culvert to the borrow pit
- Ensure capacity is adequate
- Make fence around pond so that no accidents can happen
- Provide adequate spillway
- If used for drinking water equip with slow sand filter

- Make sure the borrow pit is properly modified so there is no danger

Plan location of borrow pits (downslope of road)

Plan size/number of borrow pits (one large or several small ones)

ROAD SIDE PONDS

Water storage ponds to store water from road side drainages and culverts

- Include sediment trap and plant vegetation along water flow
- Lining with clay, geomembrane, or other techniques to avoid excessive seepage
- Proper water lifting integrated with ponds
- Make sure capacity is enough to capture the run-off water from culverts
- If used for drinking water equip with slow sand filter

- Do not place too close to road body to avoid road damage

CONSIDER USE OF SCOOPS TO CONSTRUCT

ROAD SIDE INFILTRATION PONDS

INFILTRATION PONDS

Roadside pits for soil moisture increase and prevent flooding of farmland

- Annual maintenance and road side vegetation to avoid siltation
- Install posts as well as provision of roadside plantations
- Build a small spillway for excess water

- Don't build pits to close to the road

WATER SPREADERS FROM CULVERTS

Water spreaders from culverts for suple-mental irrigation

- Use water to spread gently away from natural drain to avoid erosion
- Construct these culvert water spreaders early on so that no gully will develop
- Gently guide the water to agricultural land
- Reinforce the bund with stones when available

FLOOD WATER SPREADERS

Flood water spreaders from road surface to enhance soil moisture and recharge groundwater

- Make in direction of slope
- Make at regular distance especially when the road is slopy
- Avoid use in steep slopes

TREE PLANTING

Roadside tree planting for environmental mitigation and economic benefit

- Support local by-laws and planting of economically rewarding trees
- Select appropriate species together with communities and local experts
- Involve roadside communities in planting and maintenance

- Avoid tree planting along curves and road stretches with reduced visibility

Lessons learned

- The team has better understanding of the need for 'road water management' in its new form
- Identification of **homogenous 'beneficial road water management' units** is important to design the GL in accordance to specifics of these units
- The team has fully agreed the 'dissipate water' approach supported by the existing functional GLs by the road sector is not preferred option.
- Want to push further for this guideline to be one of the road sector GLs
- The widely varying hydrogeomorphic and agro-ecological conditions of Ethiopia make the GL easily replicable in other sub-Saharan African countries